Singing the Power Electronic: Faculty entrepreneur hall-of-famer presents a powerful way to transfer technology

By John Pastor

Laptops, televisions, cars, computer servers — practically anything that requires large amounts of data processing — have a little bit of Virginia Tech inside.

That's because since the late 1990s, companies from the smallest computer manufacturer to Intel, the multibillion-dollar technology giant that introduced the world's first microprocessors, have equipped their central processing units with a revolutionary power converter known as a multiphased voltage regulator module.

Developed by Fred C. Lee, a University Distinguished Professor and the director of the Center for Power Electronics Systems, the modules are perfect examples of a field whose purpose is to convert electricity into useful, reliable energy from sources that may fluctuate, like batteries that drain from a full charge down to nothing.

Also consider that a low-energy laptop uses less than 65 watts, while a full-sized aircraft carrier requires gigawatts. Yet electricity has to be smooth and consistent for a machine to use, no matter the machine's size or energy needs — that is power electronics.

Even science fiction writers see why it's important.

A taste for power

In the "Back to the Future" movies starring Michael J. Fox, the DeLorean time machine required 1.21 gigawatts of power to get enough oomph to span the decades.

When the onboard power source failed, Fox's character, Marty McFly, dramatically channeled electricity from a lightning strike into a fictionally realistic contraption called a "flux capacitor."

A device like Lee's multiphased voltage regulator module would be standard equipment in a time machine traversing the generations.

Making power palatable is what multiphased voltage regulator modules do. In a late-model sedan, voltage regulators channel juice from the electrical system in continual, precise amounts to at least 50 power-thirsty microprocessors.
Because Lee gave the discovery to industry rather than marketing it on a smaller scale, it became a universal solution and a prime example of how an academic research institution can transfer technology to the marketplace — and transform the world.

Today, people around the globe carry smart devices linked to cloud-based servers in their pockets, enjoy sophisticated onboard computer systems in their personal vehicles, and work with laptops in the most unlikely places — all because of Lee and Virginia Tech.

**Strategic sharing**

"If I want to be a professor and the builder of a successful industry consortium, I should be willing to share," said Lee, at work in his office in Whittemore Hall, the home of the Center for Power Electronics Systems at the Virginia Tech College of Engineering. Nearby is the center's 1,500-square-foot Future Energy Sustainable Home, a living lab powered by solar panels and an industry-supplied wind turbine on the rooftop. "Besides, you can't have your cake and eat it, too. We chose in the early days that sharing is the path we were going to take."

The center—a National Science Foundation Engineering Research Center—was formed in 1998 around five university partners and more than 80 industry members, which today include Agilent Technologies, Boeing, General Motors, GE Energy, Samsung, and Rolls-Royce.

Principal industry partners pay for membership—between $25,000 and $50,000 annually—and receive early access to intellectual property, including the now-obsequious multiphased voltage regulators.

Lee said he "had no clue" about the field of power electronics when he became a graduate student in engineering at Duke University in 1969, fresh from receiving his bachelor's degree in electrical engineering from the National Cheng Kung University in Taiwan.

But a professor named Thomas G. Wilson changed all that.

**A fateful meeting**

A practicing engineer and industry advisor for 16 years before he made the leap to academics in the 1960s, Wilson started one of the first university programs in power electronics, and eventually became chair of electrical engineering at Duke University.

Wilson doesn't typically remember his first meetings with students, but he remembers Lee.

"Fred was visiting a young lady friend in North Carolina and found out I had a program to support grad students," Wilson said. "He told me a story about power electronics. I was impressed by him. He was enthusiastic, he was interested, and he had done his homework for sure — and he had never heard of power electronics until the day before he came to see me. I confirmed this much later."

The woman Lee had been visiting is today his wife of more than 40 years, Leei. And while Lee may not have exactly known about power electronics when he met Wilson, he did know electrical engineering.
"Electrical engineering is so broad, it encompasses so many areas, that in China there might be a single college or university devoted to just one of the disciplines," Lee said. "Communication, supplies, power engineering, electronics, control, sustainability, and many other things mingle together to form power electronics. And of course when I came to this country, I had no clue … and now I am a power electronics specialist."

That he is. Wilson, an acknowledged father of power electronics, said Lee's work has been influential throughout the world.

**Faster, smaller, cooler**

In the 1950s, small components called transistors were changing the world. Capable of amplifying and switching electronic signals, these modern miracles broke the tether of 60-hertz power supplies —50 hertz in large parts of the world — by delivering reliable, fixed energy through a succession of pulses.

Portability was finally an option.

"In the early days, NASA and the Soviet Union were launching satellites into orbit, and the newspapers let everyone know when to watch for them flying across the sky," Wilson said. "But if you put a satellite into space, it's got to be lightweight, or it will never get into orbit, and it can't possibly carry enough batteries to allow it to run for years. Power has to come from solar cells, and if the power source fluctuates depending on sun or shade, it becomes very important to be able to take power in whatever form it is available, and to be able to convert it into the load that's needed."

As exciting new applications arose, Wilson and Lee were thrilled by the search for practical solutions.

"Electrical engineering was my chosen field since high school," said Lee, who came to the United States in 1969 and was named to the National Academy of Engineering in 2011. "My goal has always been to be an engineer, because engineering is always directed toward something useful that will change people's lives. I never thought of myself as a scientist, but it is applied science, if you wish."

**How to do your best**

Today, Lee is recognized along with his mentor as a world authority in power electronics.

But the teacher-student dynamic is still there. "He (Wilson) is an icon, and I continue to use him as a model throughout my professional life," Lee said. "Looking back, it's not necessarily how much I learned about power electronics from him, it's how much I learned from him as a person, as a researcher, as a man who is always driving himself to do well and at the same time driving all of his students to do the best they can."

With the right mindset, limitations can be overcome and excellence is within anyone's grasp.

"This was passed on to me, and this is what I try to pass on to my students," Lee said. "People may have a vastly different knowledge base, as well as individual strengths and weaknesses.
Some are smarter, faster, and easily grasp a concept. Others take much longer — but it really doesn't matter, if they have the right attitude. Average people can reach excellence, if they set their minds to do it."

People are amazed when they discover how high they can climb, Lee said.

"Students don't know how much potential they have until they achieve one thing in their lives that requires extraordinary effort," Lee said. "I want students to demonstrate to themselves at least in one thing that they have reached the highest ground they can possibly reach. After that, they know what it takes to reach the same level when the next challenge comes along."

Lee remembers learning at Wilson's side, wrestling with the English language and writing research papers.

"I would show him what I wrote, and I would watch him rewrite the abstract that summarized the work," Lee said. "He would use paper and pencil, write a sentence, erase it, write it, and erase it again — for hours. I'd sit in front of him, watching what he was doing, and I realized, my goodness, it's taking him two hours to write that paragraph, to make it say precisely what it should say, and he is a very good writer — shame on me for only taking 30 minutes. I realized that if I have a desire to pursue excellence, it will take a lot of effort."

**Singing the power electronic**

"Once young people get in the lab, that's when the excitement really takes off," said Elizabeth Tranter, chief of staff at Virginia Tech's Office of the Vice President for Research, who formerly worked with Lee as the Center for Power Electronics Systems' education and outreach program director. "Hands-on work is still very much a part of power electronics."

Virginia Tech started its power electronics program in 1977, and Lee was involved from the beginning. The group was known by different names over the years, including the Power Electronics Research Group and the Virginia Power Electronics Center.

Tranter, who worked to provide educational opportunities and industry experiences for pre-college and undergraduate students, said Lee has influenced the careers of hundreds of students, as well as faculty and staff members.

Through it all, he stayed close to people who had been important to him.

"He would bring together the people he worked with all of his life, and they would discuss the various issues or challenges of the day," Tranter said. "Many of these people he knew for 30 years or more. It was called the Wednesday Huddle."

Lee does not claim to be the poet laureate of power electronics, but when it comes to explaining the difficult subject, or predicting what's next in store, he is the go-to authority.

In a June 2013 invited paper to assess the state of the field in the Journal of Emerging and Selected Topics in Power Electronics, Lee and co-author Jacobus Daniel van Wyk, of the University of Johannesburg, write that growth will be driven by emerging, future applications outside of the field.
Further, they warn that explosive technological growth within the field itself creates an inward focus, making it difficult to anticipate disruptive changes.

**A special edition**

A perfect example was the November 1952 "Transistor Issue" of Proceedings of the Institute of Radio Engineers, which was a predecessor organization to today’s Institute of Electrical and Electronics Engineers.

Sitting among 48 papers on emerging transistor technology was a bold, two-page advertisement from a large industry — now long extinct — that announced plans for the full-scale research, development, and manufacture of … vacuum tubes.

Vacuum tubes, some may remember, used to be in television sets.

True enough, vacuum tubes revolutionized electronics. Without them, radio broadcasting, television, radar, sound recording, telephone networks, and computers would not have stormed the technological world. But the tubes became instant antiques, supplanted by transistors and semiconductors.

Lee said the example illustrates what happens when technology looks inward and misses the bigger picture.

**Back to the future**

As for the multiphase voltage regulator modules invented by Lee and Virginia Tech, it's unlikely they will be going the way of the vacuum tube.

Smart phones and other pocket devices are linked via the cloud to large computing machines known as data centers, which consist of many large banks of servers, and every one of them is powered by multiphased voltage regulator modules.

And it's likely that, in the cloud, power electronics and "power innovation" will meet. Google, Facebook, Twitter, LinkedIn, and Amazon are among the biggest users of cloud computing data centers. Meanwhile, McKinsey & Company, a global management consulting firm, predicts there are potentially trillions of dollars of business opportunities waiting.

In addition, Lee said, power electronics opportunities will be influenced by emerging applications in packaging, manufacturing, cooling, and environmental impact technologies, such as sustainable buildings and energy supplies.

But no mention of time travel or a real-life flux capacitor — yet.

When the time comes, it's a safe bet that Lee and colleagues will be ready to figure out how to regulate the power to make it happen.

Then, they’ll share how they did it with the world.